PERFORMANCE AND ECONOMIC POTENTIAL OF EUCALYPTUS PLANTS GROWN IN SILVIPASTORAL SYSTEMS IN PAMPA BIOME

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ABSTRACT
The aims of the current study are to assess the performance of genetic materials of eucalyptus trees planted in different arrangements, to measure the stock of forest multiproducts and to investigate the financial viability of these plantations in silvopastoral systems in Bagé (RS). Data were collected between June 2018 and August 2019, in 15 family livestock properties in 2013 and 2014. Data about plant growth (diameter at breast height, height, total and comercial volume) and mortality were collected. The economic viability of eucalyptus plantations was analyzed based on a market study and Net Present Value (NPV) and Equivalent Annual Cost (EAC) methods. It was possible concluding that the introduction of this forestry component in pastoral systems can increasing income in rural properties, both by trading forest products and using it in the property. The investment in afforesting native fields with eucalyptus has great potential to generate financial surpluses at significantly younger cutting ages than that of the economic rotation often applied to this genus in the region.
Key words: Integration systems; *Eucalyptus dunnii*; economic viability.

INTRODUCTION

Pampa biome covers an area of approximately 176,496 km², which corresponds to 62.2% of Rio Grande do Sul State territory and 2.07% of the Brazilian territory (MMA, 2019). Fields are the original and prevalent landscape in this biome, where the main economic activity lies on extensive livestock farming on native pasture – this activity accounts for approximately 70% of beef herd in the state (BOLDRINI et al., 2010; BARCELOS et al., 2016).

However, the low productivity and profitability observed for the traditional livestock farming practiced in the region has been instrumental at the time to make decisions about converting these fields into other economic activities such as crops and forestry (RIBASKI et al., 2012), which results in landscape mischaracterization process. Nowadays, fields cover 35.73% of the biome area (TRINDADE et al., 2018).

Accordingly, silvopastoral systems – which are based on the association between trees and livestock activity - can be used as alternative integrated land-use, as well as to diversify the productive matrix of rural properties by adding value to the production system already implemented in them. It can be done through timber exploitation, which (indirectly) enables avoiding livestock devaluation and its conversion into other productive activities (RIBASKI et al., 2012).

Eucalyptus is the forest species traditionally used in the region. It is associated with the rural landscape due to large forest plantations implemented under monoculture systems that were established based on financial incentives since the early 2010s, as well as to small stands "capões" implanted as windbreaks, promoting livestock thermal confort, as well as to wood reserve often without commercial purposes (ASSOCIAÇÃO GAÚCHA DE EMPRESAS FLORESTAIS, 2016). In both cases, they disregard the livestock production process in the property.

Thus, the silvopastoral system implemented with eucalyptus explores the potential of silviculture, as well as its economic and environmental benefits, based on the coexistence between native fields and livestock operations, without overlapping or replacing one another. This system can be considered innovative in the investigated region, since it has several applications in rural properties, such as producing firewood, platforms, posts, poles, as well as round and sawn wood for rural buildings, self-consumption or trading purposes.

Despite its potential advantages, this production system remains poorly used in the region. There are cultural and economic barriers to the adoption of this technology in rural properties, since these systems require greater initial financial and labor investment accounting for mid-to-long term return. Lack of knowledge about the forest product market and the difficulty to assess the wood produced in a quantitative and qualitative way are obstacles to the implementation of this system (DIAS FILHO; FERREIRA, 2008; CAMPANHA et al., 2018).

Since the adoption of this production system requires long-term resource immobilization, it must be planned in such a way to enable the production of a wide range of forest products over time. In order to do so, it is necessary previously understanding the specifications and requirements of the forest product market.

Thus, from 2013 onwards, Embrapa Pecuária Sul - in partnership with institutions such as Emater, Ministry of Agriculture, Livestock and Supply (MAPA), Bagé City Hall, Federal Institute of Rio Grande Sul and State Secretariat for the Environment - has established experimental areas and Technological Reference Units in Bagé County (RS) to allow producers to experience the implementation and management of silvopastoral systems, as well as to measure the economic outcomes from this activity to boost the adoption of this system in the region. The monitoring process adopted in these areas resulted in the current study, whose aims were to assess the performance of different genetic materials of eucalyptus trees planted at different arrangements, as well as to measure the stock of forest multiproducts and to investigate the financial viability of these plantations.

MATERIAL AND METHODS

Data were collected between June 2018 and August 2019, in 15 Technological Reference Units (TRUs) implemented in the silvopastoral project of Campanha region, Bagé County (RS). Technological reference units (TRUs) were installed in 15 family farms (area = 3 ha each) and one TRU was implemented in the experimental field of Embrapa (area = 11 ha).

The herein selected arrangement lied on trees planted in simple lines spaced 8 m, 16 m and 24 m apart, 2-m distance between plants in the rows. This arrangement corresponded to the initial number of 625, 312 and 208 trees ha^{-1}, respectively. Technical details about the implementation and management of these systems can be seen in Lucas et al. (2015).

Three eucalyptus materials - one seminal (*Eucalyptus dunnii*) and two *Eucaluptus grandis* clones (1071 and EC 06) were used in the current study. All 15 evaluated TRUs have totaled 54.5 planted hectares: 16.5 ha were planted with *E. dunnii* and 38 ha, with *E. grandis* (27 hectares planted with clone 1071 and 11 hectares planted with EC06).

One in every five rows at each planting arrangement was randomly selected in order to measure the trees. Approximately 20% of trees in each location were measured; 4.018 trees were measured, in total.

Mortality rate (%) was calculated based on the inventory carried out in the entire site. Total and commercial volume were based on rigorous cubing application to standing trees by using the Criterium RD 1000 equipment. Sample trees used for cubing were selected based on diameter class in 11 TRUs, which were defined as representative of both the species and planting arrangement. The population in each TRU was divided into 10 diametric classes; 2 trees per class were cubed - 220 trees, in total.

Stofells (1) and Spurr's combined variable (2) models were selected to estimate unmeasured trees height and volume; these models were adjusted to each TRU and planting arrangement. Subsequently, general equations were defined based on genetic material and spacing in order to estimate the volume in TRUs where trees were not cubed.

$$lnh = b_{(}o+)b_1 lnd \quad \text{Eq. (1)}$$

$$logv = b_{(}o+)b_{(}1)log\,(d^2 h) \quad \text{Eq. (2)}$$

Forest assortments were obtained through market research conducted at sawmills located in the region; assortment estimates were obtained through adjustments applied to a tapering function - in this case, the fifth-degree polynomial -, which allowed estimating the volume of forest assortments.

Usable stem was optimized for the longest logs presenting the greatest commercial value, whereas the remainders were classified in lower classes presenting shorter logs. Stems showing diameter smaller than 11.0 cm (down to the limit of 5 cm) were classified as volume for firewood in 1-meter logs. Next, log volumes were obtained and the number of pieces was calculated in electronic spreadsheet generated for this purpose.

The number of individuals in each diametric class was estimated based on genetic material and spacing. It was done by adjusting the Weibull frequency distribution model with three parameters, based on the percentile method.

Adjustment criteria such as the Adjusted Coefficient of Determination (R^2_{aj}), and Standard Error of the Estimate (in %) were used to evaluate the selected models. Standard Error of the Estimate was recalculated in case of logarithmic equation and waste distribution analysis.

Table 1 shows the costs with forestry component implementation and maintenance in silvopastoral systems based on spacing per hectare in the first two years - year 0 refers to the implementation year and year 1 refers to the post-implementation period. Technical details on operations can be seen in Lucas et al. (2015).

Table 1. Costs with forestry component implementation and maintenance per hectare, at different spacings, in silvopastoral systems located in Bagé region (RS).

Activity	**Year**	**Cost (R$) (8 x 2 m)**	**Cost (R$) (16 x 2 m)**	**Cost (R$) (24 x 2 m)**
Ant control	0	161.64	161.64	161.64
Soil preparation	0	426.0	331.3	236.7
Seedling planting and replanting*	0	974.2	422.55	545.2
Baseline fertilization	0	197.01	110.645	75.39
Chemical weeding	0	342.57	267.86	193.15
Cover fertilization	0	193.02	130.21	90.6
Chemical weeding	1	342.57	267.86	193.15
Ant control	1	75.0	75.0	75.0
Cover fertilization	1	193.02	130.21	90.6
Ant control	1	37.5	37.5	37.5
Total		2,905.03	1,897.27	1,661.40

Net Present Value (NPV) and Equivalent Annual Cost (EAC) methods were used to investigate the economic viability of the plantations, by taking into consideration interest rate of 7% a year - as provided for in the Low Carbon Agriculture Plan -, as well as duration of 5 or 6 years, which corresponded to the age of plantings at survey time.

$$NPV = \sum_{(}j = 0)^{n} [\![R_j(1+i)^{(} - j) -]\!] \ \sum_{(} j = 0)^{n} [\![C_j(1+i)^{(} - j)]\!]$$
$$EAC = (NPV * i)/[1 - [\![(1+i)]\!]^{(} - n)]$$

Wherein: Rj = revenue at the end of the year or in period-of-time *j*; Cj = costs at the end of the year or in period-of-time *j*; n = duration of the project in years or in number of periods-of-time; i = annual interest rate, expressed in units.

The cost with the land was not taken into consideration, since producers already owned the land and their goal was not to convert livestock into forest plantations, but to introduce trees in natural pastures.

RESULTS AND DISCUSSIONS

Mean growth values based on location, genetic material, cutting age and spacing (Table 2) have indicated lower variation in mortality rates recorded for *E. dunni*. The mean annual increase (MAI) in diameter recorded for this species reached 3.5 ± 0.34 cm, although it has changed depending on location and spacing. Mean annual increase in plant height reached 2.8 ± 0.22 m. On the other hand, volumetric production has decreased as spacing between lines increased - mean annual volumetric production increase reached 20.5 ± 3.4 m^3 ha^{-1} $year^{-1}$ for the smallest spacing and 5.2 m^3 ha^{-1} $year^{-1}$ for the largest one.

Table 2. Mean growth values and standard deviation recorded for estimates set for planting parameters based on genetic material, cutting age and spacing.

Species	T	Np	Esp. (m)	N (ha)	M (%)	DBH (cm)	Height (m)	Total volume (m^3 ha^{-1})
		5	8x2	526±64	19.2±9.9	17.3±1.8	15.0±1.9	105.83±17.9
E. dunnii	58 to 63	5	16x2	247±18	20.6±5.8	19.7±1.3	14.5±0.3	53.13±11.9
		1	24x2	171	17.8	15.2	12.8	25.08
		4	16x2	234±43	24.8±13.7	14.8±1.5	12.3±1.5	26.03±8.8
	56 to 58	5	24x2	149±17	25.4±12.1	14.5±1.2	11.5±1.8	17.01±7.5
E. grandis	70	2	8x2	397±184	36.5±29.5	17.6±0.1	17.1±0.7	87.05±28.1
		4	16x2	180±51	42.3±16.3	19.4±2.6	16.4±3.2	46.13±22.6
		2	24x2	137±59	34.3±28.2	19.05±3.9	15.2±2.5	31.06±18.7

Wherein: T = cutting age (months); Np = Number of evaluated plantings; Esp. = spacing; M = mortality; DBH = diameter at breast hight.

E. grandis clones recorded greater variability in the evaluated parameters due to planting in some improper areas, which led to high plant mortality and reduced growth rates.

Mean annual increase in plant diameter at 58 months reached 3.0 ± 0.27 cm, mean annual increase in plant height reached 2.6 ± 0.33 m. Mean annual increase in volume recorded 5.38 ± 1.82 and 3.51 ± 1.54 m^3 ha^{-1} $year^{-1}$ for the smallest (16 x 2 m) and largest (24 x 2 m) spacings, respectively.

Mean annual increase in plant diameter at 70 months reached 3.0 ± 0.27 cm, whereas MAI in height reached 2.6 ± 0.33 m. Volume per hectare recorded MAI equal to 5.38 ±1.82 and 3.51 ±1.54 m^3 ha^{-1} $year^{-1}$ for the smallest (16 x 2 m) and largest (24 x 2 m) spacings, respectively.

Therefore, volumetric production was overall higher in smaller spacings due to larger number of planted trees, whereas the highest productivity was observed in plantations with *E. dunnii*, which recorded the lowest mortality rate.

NPV recorded positive outcome, except for *E. grandis* (planted at spacing 24 m x 2 m) at 58 months. This outcome has indicated the financial viability of eucalyptus planting, which is capable of returning the initial investment within 5 to 6 years, at the evaluated interest rate, as well as of generating financial surplus in standing timber trading processes.

This outcome corroborates studies about the financial feasibility of eucalyptus plantations in silvopastoral systems in the Pampa biome. Oliveira et al. (2008) observed positive NPV for *E. grandis* in silvopastoral system presenting initial tree density of 500 trees ha^{-1}, at 4 years, based on interest rate of 6% a.y. Weimann et al. (2017) have analyzed the financial viability of silvopastoral systems planted with *E. grandis* in Nova Esperança do Sul County (RS) and has concluded that the implementation of the forest component in rural properties under silvopastoral system was economically viable for producers.

The potential profitability recorded for eucalyptus planting in the current study ranged from R$ 92.10 to R$ 6,062.14 per hectare and from R$ 22.5 to R$ 1,478.50 ha^{-1} $year^{-1}$, in 5 to 6-year-old trees. The highest profitability was observed for the smallest spacing, which recorded mean value of R$ 1,134.5 ha^{-1} $year^{-1}$ and the lowest profitability was observed for the largest spacing, which recorded mean value of R$ 79.75 ha^{-1} $year^{-1}$.

However, it is worth emphasizing that, despite the higher profitability, if one only takes into consideration the forest component, the 8 x 2 m spacing suppressed the native field, which is an undesirable outcome, since the production system should preferably avoid the suppression or replacement of one component by the other. It should also be capable of increasing producers' income without generating major impact on natural or cultivated forage resources and, consequently, of ensuring respect for the historical and cultural vocation of rural producers in the region, namely: livestock (VARELLA; RIBASKI, 2008).

The profitability of the herein investigated silvopastoral system was not evaluated, since the costs with, investments in, and revenues resulting from, livestock were not taken into consideration. The assessment age adopted in the current study did not express the economic rotation for timber, which is the one capable of maximizing the return from investments made in the activities of the system and in providing maximum profit to producers, which often happens at older cutting ages.

Overall, final cutting age of 7 years is often adopted as parameter for eucalyptus forests aimed at providing wood for cellulose production, as well as of 15 to 20 years for wood to be used in sawmills (WREGE et al., 2009). However, cutting age changes depending on forest management goals, growth rate, forest species, market prices for different timber uses and on production costs.

Management systems comprising older rotation age and the production of forest multiproducts are significantly profitable due to diversification in forest use and to value addition to forest products (SOUZA et al., 2007; OLIVEIRA et al., 2008; WEIMANN et al., 2017).

Ribaski (2007), Oliveira et al. (2008) and Weimann et al. (2017) conducted studies about the economic feasibility of silvopastoral systems planted with *E. grandis* in Pampa biome, based on rotation age ranging from 7 to 9 years for cellulose production, as well as on rotation ages of 14, 15 and 21 years for sawn wood production – plants were subjected to 1 or 2 thinning procedures at intermediate ages.

However, the decision about the right time to harvest the wood depends on producer's planning in terms of need of financial resources and market opportunities. It is worth emphasizing that larger and older trees reach bigger dimensions and they can be used to produce more noble products, with higher added value.

CONCLUSIONS

The introduction of the forestry component in traditional pastoral systems practiced in Bagé region can help increasing income in rural properties, both through forest product trade and through the use of such a product in the property.

If one only takes into consideration the economic benefits resulting from timber trading, the investment in afforesting native fields with eucalyptus trees has great potential to generate financial surpluses at significantly younger cutting ages than that of the economic rotation often used for the investigated genus in the region.

Although the spacing of 8 x 2 meters presented the highest profitability, it is not recommended if the goal is to maintain livestock activity in the area, since excessive shading has suppressed native forage plants.

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